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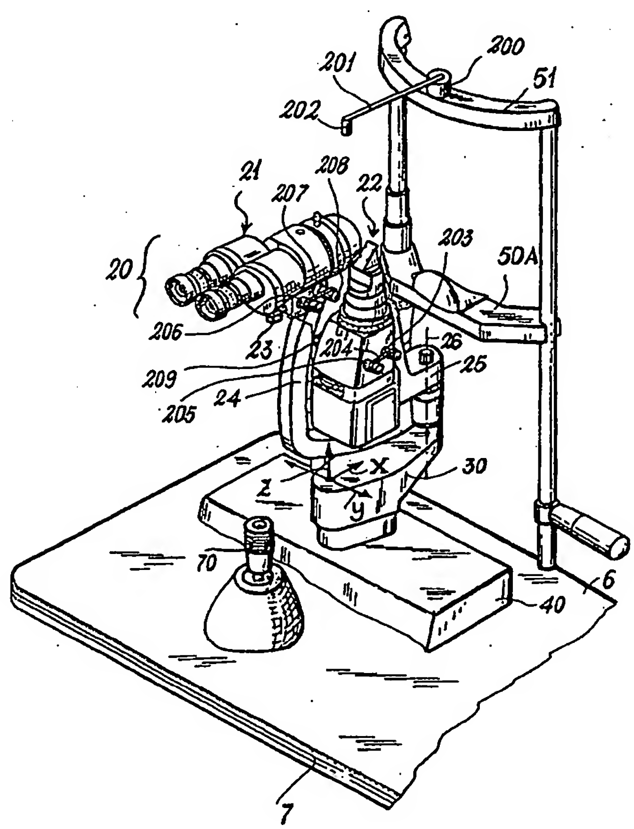
(54) Title: SLIT LAMP FOR THE OBJECTIVE OPHTHALMIC EXAMINATION OF THE PATIENT

(57) Abstract

A slit lamp for objective ophthalmic examination comprising an observation optical unit and an illumination optical unit which are movable jointly in the directions (x, y, z) of cartesian space and angularly movable separately about a common axis. The movements of these optical units, effected by servo-controls, are measured and memorized. They are associated or associable with the slit lamp means for monitoring the conditions of the light source, and image acquisition means for data storage (memorizing) or for real time evaluation of distance, thicknesses, luminous intensity and colour. The lamp can be controlled by computer, possibly via voice synthesis, this control also possibly involving a rotatable table on which the slit lamp can be mounted, together with other instruments.



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SLIT LAMP FOR THE OBJECTIVE OPHTHALMIC EXAMINATION OF THE PATIENT

This invention relates to a slit lamp for the objective ophthalmic examination of the patient. The slit lamp is of the type comprising an observation optical unit of binocular type and an illumination optical unit, these two optical units being supported within the lamp in such a manner as to undergo in unison controlled movements along three mutually perpendicular axes, namely a vertical axis (z axis), a second axis (x axis) directed towards the patient and a third axis (y) perpendicular to the other two, each optical unit being mounted rotatable about the same vertical axis independently of each other.

The invention also relates to a multi-functional centralized apparatus which includes the slit lamp as its main component, together with other ophthalmic devices which by way of example can include frontotocometers, autorefractometers, optotypes, tonometers and other devices.

The invention also relates to the control of ophthalmic instruments by a personal computer (PC) operated partly or mainly by voice synthesis.

Slit lamps are widely known in the most varied constructions, They can incorporate or associate photographic, cinematographic or television filming apparatus for record storage or other reasons well known in the ophthalmic sector. The unison movements along the three axes are controlled by a joystick lever by which the operator applies the physical force necessary to move the slit lamp. This is therefore a basically primitive manual mechanical

system which because of its nature is not of particularly high precision, which would however be desirable if the data relative to the positions assumed during use were to be used later with the same patient. In other words reproducibility of a given situation cannot be ensured.

It must also be added that the angle of the two optical units (observation and illumination), the slit width, the optical unit magnification and the position of the reference light for the eyes are not only manually adjusted by the operator, but their reading is always difficult because this has to be done on circular graduations located in a semi-hidden position, and are not always accurate as they depend on the human factor.

The luminous intensity of the light source of the slit lamp is subject to decay with time, this decay prejudicing proper execution of the ophthalmic measurement. Hence this is also to be remedied.

In addition to the slit lamp which represents its main component, an ophthalmic consulting room possesses various other instruments, at least a further three, which not only occupy precious space but also require the patient and specialist to move from one to the other when the need arises, unless they themselves are moved in front of the patient, which is likewise uncomfortable. This means that the functionality of the consultation suffers, if not other than for the loss of time which could otherwise be profitably employed. Centralization within a multi-functional arrangement which also facilitates functional handling is hence desirable.

It is well known that voice synthesis, ie the technique of recognizing the voice and translating it into commands or writing, has in recent years, especially with self-learning, attained results such as to be able by means of a computer to control even complex operations, with at least partial elimination of the feeding of commands, for example via keyboards.

The objects of this invention derive from the aforesaid considerations, namely to provide a slit lamp which besides being of high precision, simplicity and ease of use, is also distinguished by being computer controlled and, because of its constant precision, provides repeatable data useful for both diagnostic and surgical purposes. A further object of the invention is to provide a slit lamp in which the angles of the optical units (observation an illumination), the slit width, the optical unit magnification and the angle of orientation of the reference light for the eyes are not only easily displayed but are also objectively valid, memorizable and reproducible. A further object of the invention is to determine the operational state (decay) of the light source of the slit lamp in order to be able to replace it in good time. A further object is to be able to produce movement of the slit lamp without force and with high precision. A further object is to associate the slit lamp with other instruments useful to the ophthalmologist in such a manner as to be able to selectively bring one or other of these instruments in front of the patient and ophthalmologist without the need to manually pick up and move the instruments. A further object of the invention is to be able to measure in real time morphological characteristics such as areas, distances, intensities (and/or colour) and in particular thicknesses of eye structures (by the use of sensors on the slit lamp).

These and further objects which will be apparent from the ensuing detailed description are attained by the invention, the inventive characteristics of which will be apparent from the accompanying claims.

The invention will be more apparent from the detailed description of some preferred embodiments thereof given hereinafter by way of non-limiting example and illustrated on the accompanying drawings, on which:

Figure 1 is a schematic view from above of an apparatus with a stepwise-rotatable table on which there are mounted various

instruments for optical unit use, including a slit lamp;
Figure 2 is a perspective view of a slit lamp according to the invention;
Figure 3 is a schematic plan view of the members by which the slit lamp is moved along the three directions of the cartesian space xyz;
Figure 4 is a schematic section through a detail of the slit lamp, this detail regarding the side on which the two arms relative to the observation and illumination optical units are connected;
Figure 5 is a schematic detailed view relative to the means by which the slit lamp is moved in the direction z; and
Figure 6 is a block diagram relative to the control of the rotatable table of Figure 1 and the slit lamp.

In the figures, the reference numeral 1 indicates overall a rotatable table mounted on a base 2 containing motor means which on command, for example provided by a keyboard or computer, rotate the table through 90° steps. The motor means 3 can be a controllable geared electric motor which transmits movement to the table via a toothed belt. In four positions spaced apart by 90°, the table comprises four support platforms 3, 4, 5 and 6 which are mounted radially slidable on conventional guides 7, to be able to pass from a withdrawn inoperative position to an advanced operative position in which the platform, the platform 3 in the case of Figure 1, lies within the space between the patient and ophthalmologist, respectively seated one in front of the other on the chairs 8 and 9, which are adjustable for example in height under the control of the keyboard, or better still by the computer, for example by voice synthesis.

The support platforms 3, 4, 5 and 6 can be driven in various ways, for example by a rack 11 and pinion 10, in which the pinion 10, mounted on the table, is rotated by its own geared motor, not shown but also mounted on the table, the cooperating rack being fixed to the lower face of the support platform. On each extractable support platform there can be mounted an ophthalmic instrument, of which the most important is a slit lamp for the

objective examination of the eye, an example of the lamp being shown in the other accompanying Figures 2-5 in which it is indicated overall by 20, and can also be seen in Figure 1 in which it lies on the movable support platform 6.

To use the slit lamp 20, the ophthalmologist operates a dedicated keyboard or the keyboard of a computer or uses voice synthesis associated with this latter, to cause the support platform 3 to withdraw, the table to rotate through 90°, and the support platform 6 to advance, this carrying the slit lamp 20 to be used. The geared motors which operate the pinions 10 for moving the support platforms 3, 4, 5 and 6 and which are positioned on the table, to hence rotate with it, are electrically powered via cables after the utilization position of the required platform or instrument has been attained.

Figure 2 shows overall a possible embodiment of a computerized slit lamp 20 according to the invention. As is well known, the slit lamp comprises a binocular observation optical unit 31 and an illumination optical unit 22. The binocular optical unit 21 has a connector 2 to which a photographic camera, a cine camera or a video camera can be connected and which can be controlled in various ways, for example by a keyboard or voice synthesis computer, for acquisition of images to be memorized and for camera control. The filmed images can be memorized on the computer in a file dedicated to the patient.

In this example the two optical units 21, 22 are carried by a separate arm 24, 25, the two arms having a common vertical axis 26 about which either one can be rotated independently of the other, either manually or by servo-controls. The two arms are rotatably supported in known manner by a common support member 30.

The rotation of one and other of the arms can be measured by known measurement means, for example electrically by known 360°-rotatable potentiometers. The electrical output signal from the potentiometers is conditioned and processed to obtain the angular

position of the arms. The angular positions are memorized and used subsequently to reset the initial conditions. A non-limiting example of the use of the two potentiometers is shown in Figure 4 in which they are indicated by 31 and 32. They are rigidly fixed to the support member 30, including via a support arm 30A. One, namely the potentiometer 31, is rotated by a toothed belt 33 and sprocket wheels 34, 35 rigid with a pin fixed to the arm 25 on the axis 26 and with the potentiometer shaft respectively. The other, namely the potentiometer 32, is rotated by a toothed belt 36 and sprocket wheels 37, 38 rigid with a pin 39 positioned on the axis 26 of the arm 24 and passing through the member 30, and with the potentiometer shaft respectively.

On the arm 25 of the illumination optical unit there are two rotatable selectors (knobs) 205 and 209 with which the operator respectively selects the width of the lamp slit and the relative diaphragm. With these knobs he selects the suitable slit size for the ophthalmic examination. On the arm 24 of the observation optical unit 21 there is a rotatable selector (knob) 206 with which the optical unit magnification can be set. In a manner equivalent to that of Figure 4, each knob comprises a coaxial sprocket which transmits the movement impressed by the operator on the knob to a rotation encoder, or to a potentiometer (203, 208) or the like by way of a sprocket mounted on the axis of the encoder or the like, via a toothed belt (204, 207). For reasons of simplicity the belt transmissions and encoder or the like which are represented (and hence visible) are those relative to the knobs 205, 206.

On the support 51 there is positioned an arm 201 (of about 30 cm in length) carrying at one end a reference lamp 202 for the patent's eyes, the other end being rigid with the rotation shaft of a rotation encoder 200 (or potentiometer or the like). Said encoder 200 is positioned at the centre of the headrest 51. The values manually set by the operator by means of said knobs, these values being the slit width, the diaphragm dimensions, magnification and position of the reference light for the

patient's eyes, are hence measured by encoders or potentiometers or similar position sensing means, the output signals of which when conditioned and processed represent the values of the quantities measured, these values being memorized (computer E) and used for objective comparison of the ophthalmic examination.

The support member 30 for the arms 22, 24 and for the optical parts carried by these extends through a movable casing 40 connected within and able to undergo movements within the cartesian space xyz, where x indicates the direction perpendicular to the patient (his chin resting against the conventional chin rest 50 and his forehead resting against the headrest 51 carrying the chin rest 50), z the vertical direction and y the direction perpendicular to the two preceding directions.

To be able to undergo these movements (see Figures 3 and 5) the member 30 is provided with a threaded rod 31A and sliding pins 32A. These pins are mounted slidable within axial bearings 33A mounted in seats present in a slide 3A. The threaded rod 31A screws into a nut-screw 35A mounted rotatable within the slide 34A via a bearing 36A and a bush 37A, and provided with an appendix projecting lowerly from the slide 34A and on which there is fixed a sprocket 38A driven by a sprocket 39A via a toothed belt 40. The sprocket 39A is mounted on the shaft of a stepping motor 41 fixed to the slide 34A. The reference numeral 90 indicates a compensating compression spring. Hence when activated, this motor is able to produce the vertical movement (ie along the z axis) of the slit lamp. The extent of the movement can be measured by a conventional position encoder or other known equivalent means, and is transmitted to a computer E (Figure 6).

The slide in question is mounted slidable via axial bearings 42 along two parallel guide bars 43 positioned in the y direction and forming part of a further underlying slide 42A movably supported, in a manner similar to the preceding, on a pair of parallel bars 45A, extending in the x direction and fixed for example to the support platform 6 or to a part of the actual base of the slit

lamp.

The slide 34A is driven along the two guide bars 43 of the underlying slide 42A by a stepping motor 44 mounted on said slide 42A, and of which the drive shaft transmits movement to a screw 45 engaging in a corresponding threaded hole provided in the slide 34A. Hence when the stepping motor 44 is activated the slit lamp moves in the y direction. The extent of the movement is measured by a position encoder which feeds the relative data to the computer.

The underlying slide 42 moves in the x direction along the guide bars 45A under the action of a stepping motor 48 driving a screw 49 which screws into a correspondingly threaded through hole in a piece 50 mounted on the slide 42A. Again in this case the position assumed in this direction is determined by a conventional position encoder which feeds the data to the computer.

The position of the encoders or other equivalent means (such as optical bars) or other position sensors is obvious to the expert of the art on knowing what the encoder or the like is required to measure, as has been indicated.

In addition, although not shown, for each of the directions of movement (x, y, z) there are provided two limit switches of obvious operation, their function being to limit the travel along the directions (x, y, z) of the slides (directions x, y) and of the member 30 (direction z). Again in this case the position of the switches is obvious to the expert of the art knowing the particular travel involved.

The movements in the three stated directions (x, y, z) can be obtained by a joystick-type control lever 70 secured to the base of the lamp and operating on six switches, two for each of the three directions, each one of the two being for one of the senses of the same direction. Moving the joystick in the directions x and y produces slit lamp movements in these directions, movements

in the z direction being obtained by rotating the joystick about its own axis. At its top the joystick comprises a pushbutton by which the three items of data relative to the position (x, y, z) assumed by the slit lamp are fed by the operator to the computer E in the form of a string.

At another point of the apparatus there is provided another pushbutton (reset) by which, when the examination has been effected, the slit lamp 20 is returned to a given starting position corresponding to the value "zero" on the position measurement means (encoder).

As already stated, it will be assumed that the rotatable table (Figure 1) has moved the slit lamp 20 into its utilization position, for example as the result of a command fed by the ophthalmologist via a keyboard T (see Figure 6) or via the computer keyboard TP or by a voice synthesis command which replaces the command fed via the computer keyboard TP. If the command is given using the computer E the keyboard T is excluded by action on the auxiliary card AX (Figure 6) by the central processing unit CPU addressed by the computer E via the RS232 serial line.

The slit lamp 20 is in the zero position of the three directions x, y, z (totally to the rear, totally to the left and totally down, with reference to Figure 2). The patient rests against the chin rest 50 and the headrest 51. By operating the joystick 70 the ophthalmologist obtains the corresponding movement of the slit lamp 20 via the CPU which as already stated acts on the stepping motors via a power driver, each associated with one motor. These stepping motor units and drivers are indicated in Figure 6 by "actuator + driver x axis, y axis, z axis". The drivers are controlled by the CPU such that on initial movement of the joystick 70 there is movement of only one pulse in the required direction, then if the joystick is maintained in that direction for a certain time, for example ½ second, the instrument accelerates and moves with maximum speed. On releasing the

joystick there is immediate stoppage. Having obtained the desired movement in the three directions the means (in this example the position encoders) feed the computer E via the CPU and the RS232 serial line with the data relative to the final position assumed by the slit lamp 20, as required by the ophthalmologist. It should be noted that the encoders used as position sensors in the described example can be replaced by electronic counting means which are incremented or decremented, depending on the direction of rotation of the stepping motors, for each of their movement pulses. Taking account of the geometry of the system (ie of those members which transmit movement from the stepping motors to the slides and to screw means for movement along the z direction), the data or string relative to the final position assumed by the instrument is easily processed by the CPU, this data or string being fed through the RS232 line to the computer which memorizes it and can easily, quickly and automatically reset the position, by acting on the stepping motors by bypassing the joystick 70, on the occasion of a new examination of the patient, so allowing an exact evaluation of any development of determined states which have been previously observed. It also enables the ophthalmologist to reset the angular position of the two optical units.

The computer E can be used to control not only the rotatable table and the other instruments present on it, but also to set the inclination and height of the patient's chair and to vary the room lighting. In addition to providing sophisticated handling of the filing of the typical data of a doctor-patient relationship, the computer also provides sophisticated handling of important data for further use (for example geometrical conditions, ie the aforesaid xyz data, adn data regarding illumination and ophthalmic images filmed by the photographic, cine or video camera). For example, the images obtained by cameras are acquired by the computer via a frame grabber card in real colours which can be compared with those of subsequent examinations.

An important factor for a correct examination by the slit lamp is

substantial constancy of the luminous intensity of the relative light source, which by nature tends to decrease with time. This substantial constancy can be maintained in two ways, namely by replacing the light source when degraded or by increasing the supply voltage within reasonable limits. In both cases, the invention proposes to use as the sensor a photodiode positioned in an illuminated zone without interfering with the beam leaving the slit. The electrical output signal from the photodiode, amplified if necessary, is compared in a comparator circuit with a reference value (representative of the optimum luminous intensity). This comparison produces an error signal which can be used to visually indicate insufficient luminous intensity and request replacement of the light source, or increase in the voltage applied to the old light source, but only as far as a preset limiting value (via another comparator) beyond which a visual signal is obtained requesting replacement of the light source.

Claims:

1. A slit lamp comprising an observation optical unit and an illumination optical unit which are movable in unison within cartesian space (x, y, z) and positionable independently of each other about a common vertical axis, characterised in that the movement of the optical units within cartesian space is effected by motor means, means being provided for measuring the extent of said movement.

2. A slit lamp as claimed in claim 1, wherein the motor means comprise stepping motors, one for each of the directions of movement (x, y, z).

3. A slit lamp as claimed in claim 1 or claims 1 and 2, wherein the movement in the z direction is effected by a stepping motor which operates via a screw linkage.

4. A slit lamp as claimed in one or more of the preceding claims, wherein the stepping motor relative to the z direction is mounted on a slide which supports the two optical units and the screw linkage.

5. A slit lamp as claimed in claim 4, wherein the slide is movable along guide means in the y direction under the action of another of the stepping motors, said guide means forming part of a structure movable in the third direction x and supporting said stepping motor, which acts on the slide via a screw linkage.

6. A slit lamp as claimed in claim 5, wherein the structure movable in the x direction is driven via a screw linkage along stationary guide means in said direction by the third stepping motor, which is stationarily supported.

7. A slit lamp as claimed in claim 1 and one or more of the preceding claims, wherein the means for measuring the extent of movement within cartesian space (x, y, z) are position sensors,

such as encoders (linear or angular), optical rings or the like, their outputs, representative of the extent of movement, being memorized in a computer so as to be able to be used by the computer to reset the same extent of movement on subsequent occasions, for example by means of a mouse, keyboard or voice synthesis, or be used to calculate thicknesses, distances and intensities (and/or colour) in real time.

8. A slit lamp as claimed in one or more of the preceding claims, wherein the movement of the optical units within cartesian space is effected by an analog device (such as a joystick) acting on a processor (CPU) which controls the stepping motors.

9. A slit lamp as claimed in one or more of the preceding claims, wherein the analog device, if in the form of a joystick, operates with three pairs of switches, two for each of the three directions in the cartesian space (x, y, z), one of these pairs, namely that relative to the z direction, being activated by moving the joystick angularly about its axis.

10. A slit lamp as claimed in one or more of the preceding claims, wherein with each of the optical units there are associated means for measuring their angular positions about the common axis of rotation, these being indicative of the angle of observation and of the angle of illumination respectively.

11. A slit lamp as claimed in claim 10, wherein the measuring means are potentiometric sensors, the converted data from which are transmitted to the computer.

12. A slit lamp as claimed in one or more of the preceding claims, wherein the positions representing the angles of the optical units, the magnification value, the slit width and the optical unit magnification are set by servo-controls or by any type of encoder (electrical, optical or magnetic).

13. A slit lamp as claimed in at least claim 1, wherein with

the illumination optical unit there is associated a sensor for measuring the illumination intensity of the light source of the optical unit (such as a photodiode, photoresistor, photomultiplier, photoelectric cell or the like), the output signal of said sensor being used to request replacement of the light source or increase in the light intensity.

14. A slit lamp as claimed in one or more of the preceding claims, wherein with the observation optical unit there are associated image acquisition means such as a photographic camera, cine camera or video camera, the images from which are acquired by a computer, the camera being program-controlled in such a manner as to optimize amplification.

15. A slit lamp as claimed in one or more of the preceding claims, characterised by being mounted on a platform which can be selectively and radially advanced and withdrawn on a stepwise-rotatable table carrying further instruments used in ophthalmic examination, some of which are arranged on similar platforms angularly spaced apart.

16. A slit lamp as claimed in one or more of the preceding claims, wherein the movements of the table, including those of the relative platforms, are controlled by a keyboard or a computer, possibly by voice synthesis.

17. A slit lamp as claimed in the preceding claims, with which means are associated for measuring the angular position of the reference light for the patient's eyes, the slit width and the optical unit magnification.

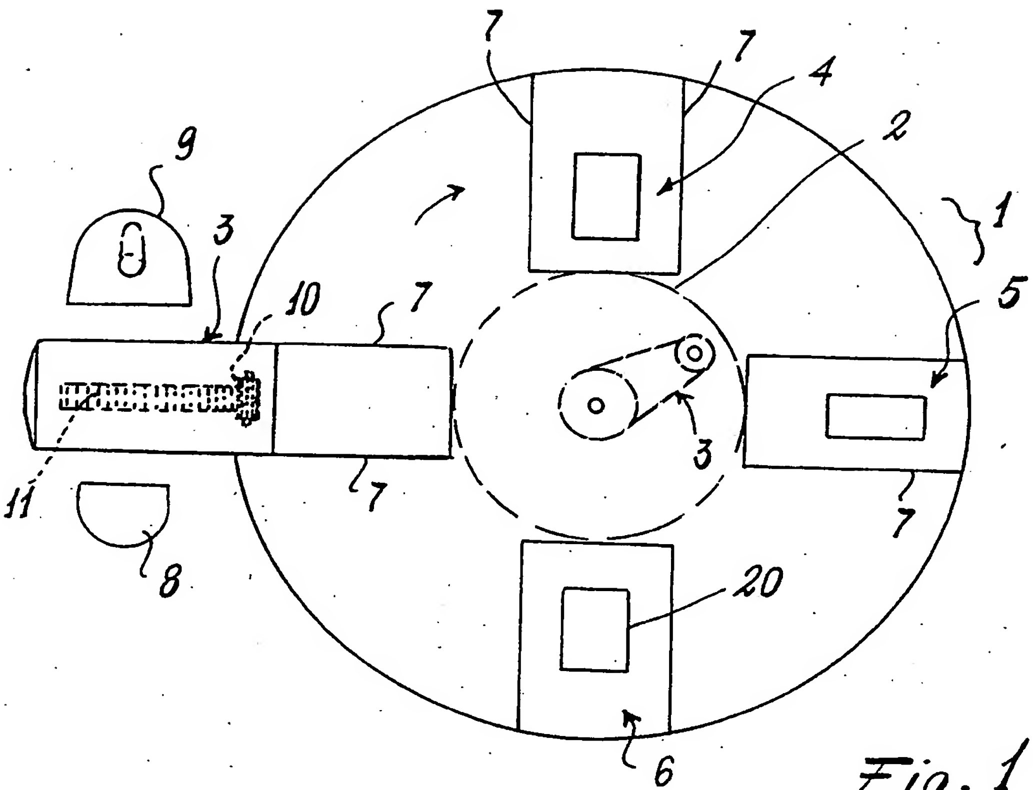

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Fig. 1

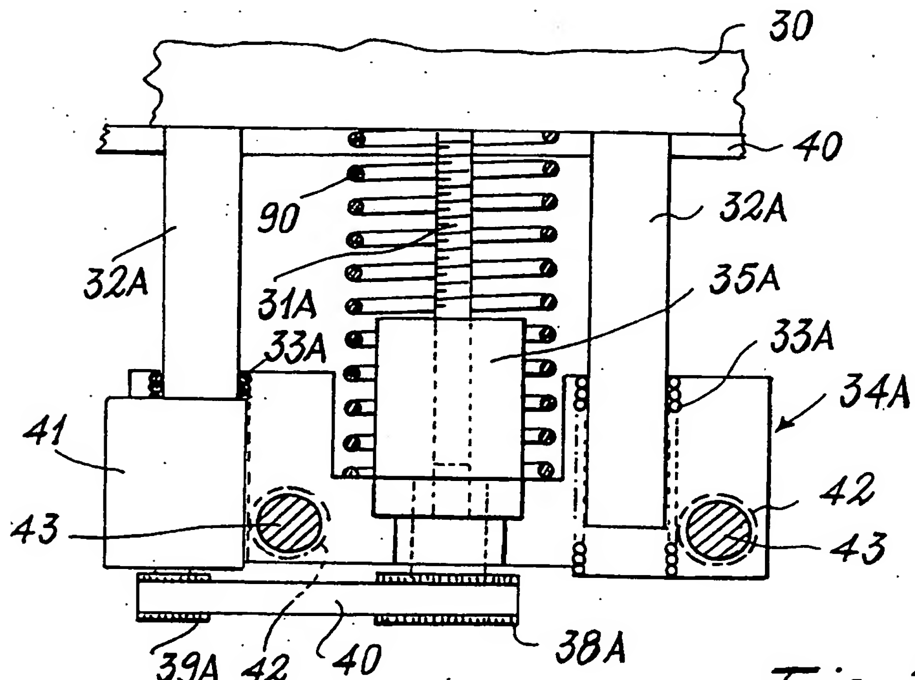

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Fig. 5

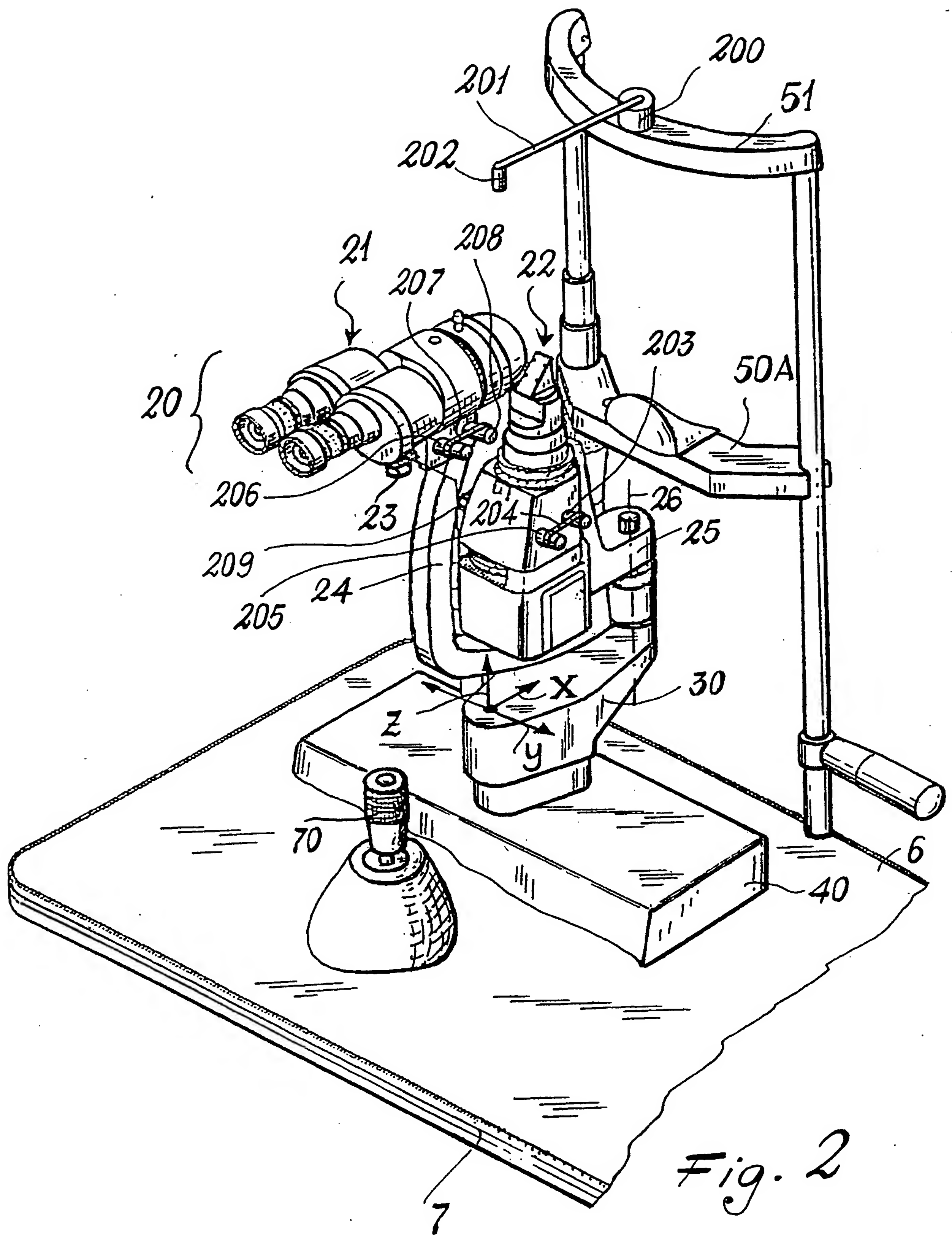
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Fig. 2

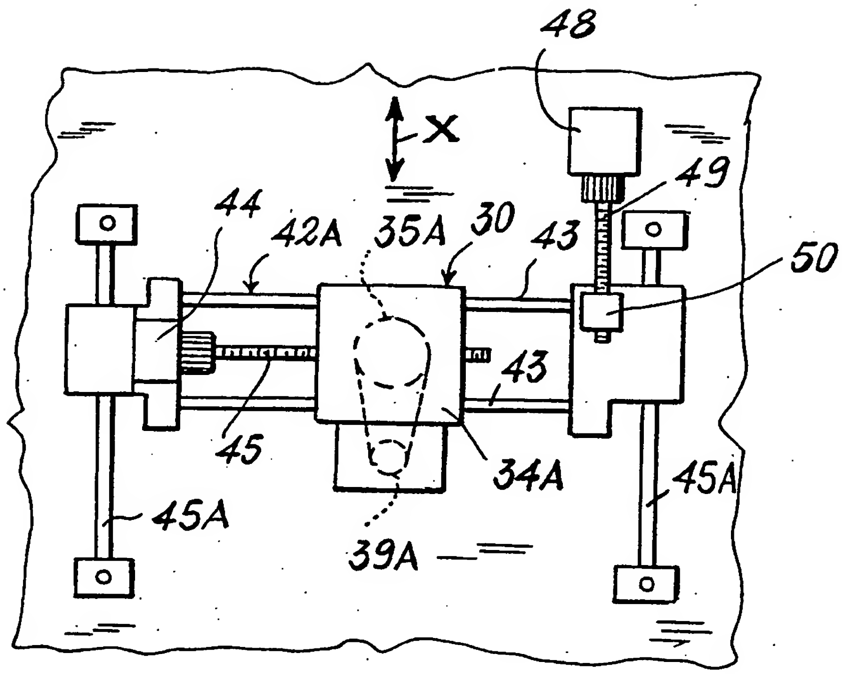
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Fig. 3

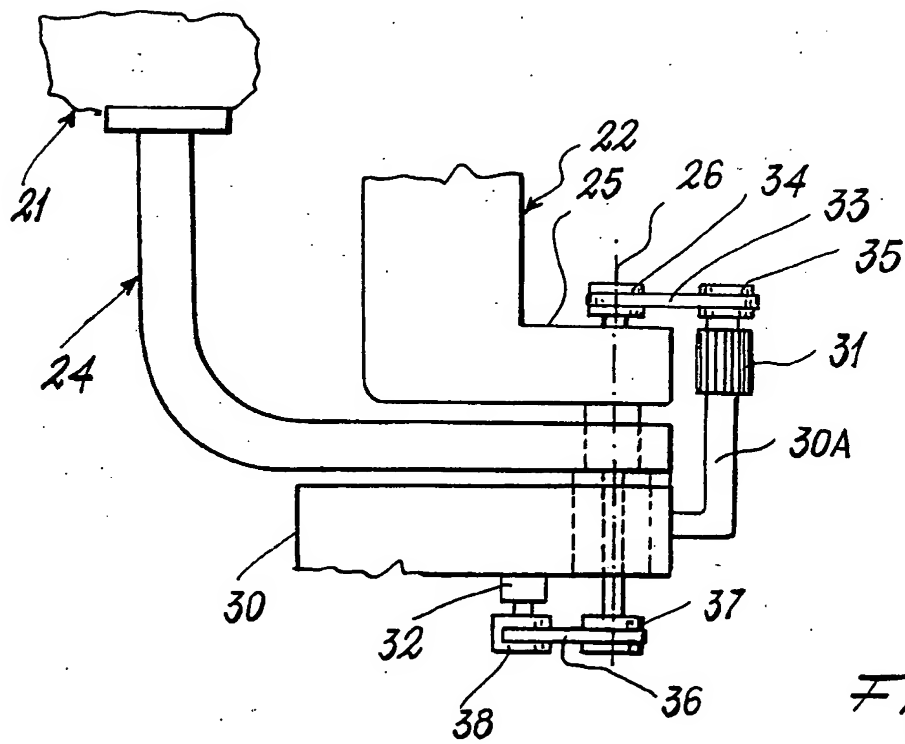
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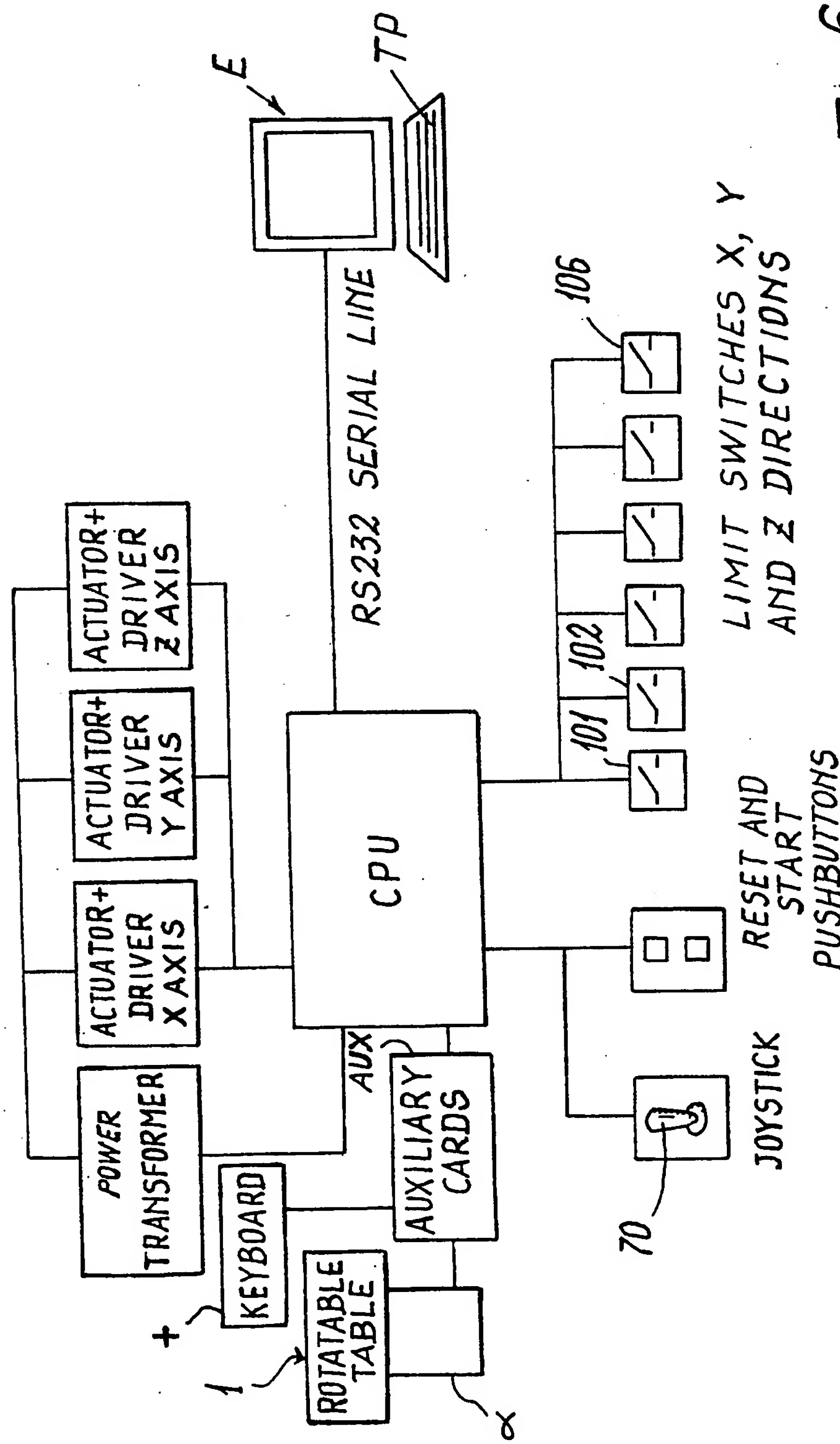
Fig. 4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ACTUATOR+ DRIVER Y AXIS
ACTUATOR+ DRIVER X AXIS
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CPU
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Fig.6

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 99/02564

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 A61B3/135

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4 925 293 A (HURD WILLIAM C) 15 May 1990 (1990-05-15) column 2, line 50 - column 3, line 32 column 5, line 1 - column 6, line 3; figures	1-4,7
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[X] Further documents are listed in the continuation of box C.

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16 August 1999	24/08/1999

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 99/02564

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
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